Name: ____ Date: ____________________ CHEM 1A

Monday/Tuesday - October 28 & 29, 2019 - Properties of Gases & Gas Stoichiometry: (Chapter 5 Pt 1)

I. Big Idea –

Pressure: 1atm = 760 torr = 760 mmHg

Temperature: T(Kelvin) = T(Celsius) +273.15

STP Conditions: 273.15K (0 C), 1atm

SATP Conditions: 298.15 K (25C), 1atm

Let's think about the three physical states of substances: solid, liquid and gas. Today we're going to think about gas (*Solid and Liquid we'll do in 1C).* Chemical properties for gases vary significantly, but physical properties are simpler to talk about: Gases occupy the full **volume** of their containers.Gases also have a **pressure** and a **temperature**. By looking at these properties, we can understand the behavior of gases.

11 elements are gases under standard conditions
$H_2, O_2, F_2, Br_2, I_2, N_2, Cl_2, He, Ne, Ar, Kr, Xe, Rn$

As well as low molar mass compounds such as
HCl, CH_4, C_3H_8

Gases are **compressible**, and they fill up the space that is available. This implies that **the molecules are moving quickly in chaotic motion.**

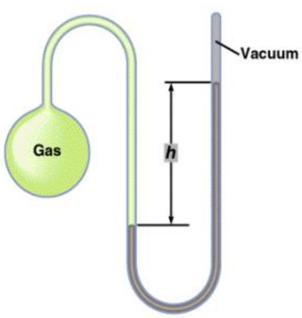
II. Pressure in Systems

1. A glass column is filled with mercury and inverted in a pool of mercury. The mercury column stabilizes at a height of 735 mm above the pool of mercury. What is the pressure of the atmosphere? 0.967 atm

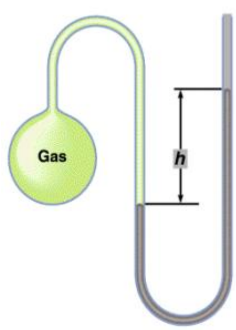
Barometers

Height = gravity + Pint + Pext

2. Determine the pressure (atm) of the gas in the flask.
   a. h = 0.15 m
   b. h = 0.08 m, $P_{atmoshpere}$ = 1 atm



h (in mm) = |ΔP (in torr)|
$h = |P_{gas} - P_{vacuum}|$
h = 0.15 m = 150 mm
$150 = |P_{gas} - 0|$
P_{gas} = 150 torr
$150\ torr \frac{1\ atm}{760\ torr} = 0.197\ atm$



h (in mm) = |ΔP (in torr)|
$h = |P_{gas} – P_{atmosphere}|$
h = 0.08 m = 80 mm
$80 = |P_{gas} - 760|$
P_{gas} = 840 torr
$840\ torr \frac{1\ atm}{760\ torr} = 1.1\ atm$

III. The Ideal Gas Law: ______________________

What makes an ideal gas/ideal conditions?
-High temp
-Low pressure
-Small particle size
-Low interaction btw particles

1. What volume (in L) is occupied by 35.2 g of nitrogen at 35°C and 0.975 atm?

PV = nRT; m=35.2g, MW = 28.02 g/mol of N_2
N = 35.2g N2 (1 mol/28.02 g N2) = 1.26 mol N2
T = 35C = 35 + 273.15 = 308K
V=nRT/P = (1.26mol)(0.08206 Latm/molK)(308K)/(0.975 atm) = 32.7L

2. A 36.4 L volume of methane gas is heated from 25˚C to 88˚C at constant pressure. What is the final volume of gas?

V1/T1 = V2/T2 and therefore V2 = V1*T2/T1 = (36.4L)*(361.15K)/(298.15K) = 44.1L

3. A sample of oxygen gas has a volume of 4.50 L at 27°C and 800.0 torr. How many oxygen molecules are in the sample?

# of molecules can be derived from moles
PV = nRT $n = \frac{PV}{RT}$ $n = \frac{(800torr)(4.5L)}{(62.37torrL/molK)(300K)}$ *n = 0.192 mol*
0.192 mol x $6.022x10^{23}$ molecules/mol = $1.16x10^{23}$ molecules

4. The empirical formula of a gas is CH_3O. If 2.77 g of the gas occupies 1.00 L at exactly 0°C at a pressure of 760 Torr, what is the molecular formula of the gas?

A) $C_3H_9O_3$ B) $C_5H_{15}O_5$ C) $C_4H_{12}O_4$ D) $C_2H_6O_2$ E) CH_3O

PV = nRT => (1 atm)(1 L)= n(.8206 L*atm/mol*K)(273K); n = .0446 moles
2.77g/ # of moles = 62.1 g/mol; EF mass = 12.01+ 3(1.01) + 16 = 31.03 g/ mol
Multiply by 2 to get 62.1 g/mol Therefore, the answer is 2. C2H6O2.

5. In an experiment, 405 mL of methane gas was collected over water with a total pressure of 785 torr at 30°C. What is the vapor pressure of water (in torr) at 30°C if 0.258 g of methane was collected?

$P_{Total} = P_{CH_4} + P_{H_2O}$

$P_{CH_4} = \frac{nRT}{V} = \frac{\left(0.258\ g\frac{1\ mol}{16.026\ g}\right)\left(0.08206\ \frac{atmL}{molK}\right)(30+273K)}{0.405L} = 0.988atm\ \frac{760\ torr}{1\ atm} =$ 751 torr

P_{H_2O} = 785 torr – 751 torr = 34 torr

6. A 275.0-mL sample of O_2 is collected over water at 60.0°C. The total pressure is 755 torr. What is the volume of the O_2 at STP? (The vapor pressure of water at 60°C is 149 torr).

(A) 180.0 mL (B) 224.0 mL (C) 244.0 mL (D) 333.0 mL (E) none of these

$P_{Total} = P_{O2} + P_{H_2O}$, P_{O2} = 755-149 = 606 torr. $V2 = V1 * \frac{P1*T2}{P2*T1} = \frac{(275.0\ mL)(606\ torr)(273K)}{(760\ torr)(333K)}$ = 180 mL

Partial Pressure (P_X):
The pressure of one of the gases in a mixture
Dalton's Law of Partial Pressures:
Ptot = Pa + Pb ….
Mole Fraction:
Xa = na/ntot

7. Calculate the density of Hydrogen Bromide gas in g/L at 733 mmHg and 40 °C.

$$PV = nRT\ \Rightarrow\ PV = \frac{m}{M_u}RT;\ \rho = \frac{m}{V};\ \frac{P*M_u}{RT} = 3.04\ \text{g/L}$$

8. A mixture of gases contains 0.31 moles of CH_4, 0.25 moles of C_2H_6, and 0.29 moles of C_3H_8 and the total pressure of the system is 1.50 atm. What is the partial pressure of CH_4?

$$P(CH4) = \frac{n(CH4)}{n(tot)} P(tot) = \frac{(0.31\ mol)}{(0.31 mol + 0.25 mol + 0.29 mol)} (1.50 atm) = 0.55 atm$$

9. A mixture of oxygen and helium is 92.3% by mass oxygen. What is the partial pressure of oxygen if atmospheric pressure is 745 Torr?

If you had a 100 g sample ⇒ 92.3 g of O_2 and 7.7 g of He

$$\frac{92.3\ g\ O_2}{31.998\ g/mol} = 2.88\ mol\ O_2 \qquad \frac{7.7\ g\ of\ He}{4.0026\ g/mol} = 1.92\ mol\ He$$

$$P_{O2} = X_{O2}P_{total} = \left(\frac{2.88\ mol\ O_2}{4.80\ total\ mol}\right) 745\ torr = 447\ torr$$

10. Given a cylinder of fixed volume filled with 1 mol of argon gas, which of the following is correct? (Assume all gases obey the ideal gas law.)
(A) If the temperature of the cylinder is changed from 25°C to 50°C, the pressure inside the cylinder will double.
(B) If a second mole of argon is added to the cylinder, the ratio *T*/*P* will remain constant.
(C) A cylinder of identical volume filled with the same *pressure* of helium must contain more atoms of gas because He has a smaller atomic radius than argon.
(D) Two of these are correct. (E) None of these is correct.

11. Which of the following relationships is *not* true?
(A) *PV* = constant when temperature and moles of gas are held constant.
(B) *V/T* = constant when pressure and moles of gas are held constant.
(C) *nT* = constant when pressure and volume are held constant.
(D) *P/n* = constant when volume and temperature are held constant.
(E) All of these are true.

12. Consider a sample of neon gas in a container fitted with a movable piston (assume the piston is massless and frictionless). The temperature of the gas is increased from 20.0°C to 40.0°C. The density of neon
(A) increases less than 10%. (B) decreases less than 10%. (C) increases more than 10%.
(D) decreases more than 10%. (E) does not change.

IV. Other Equations of State

The ideal gas law does not account for a couple properties of real gases. Real gases _have size_ and feel attraction__.

Ideal Gas Law: PV = nRT

Van der Waals Equation State:

(P+a(n/v)^2)(V-nb)=nRT

a= correction for attraction

b=correction for size

Virial Equation of State (experimental data)

PV = nRT (1 + B/Vm + C/Vm2 …..)

1. Calculate the pressure exerted by 0.5000 mole of N_2 in a 1.000-L container at 25.0°C. Use the van der Waals equation. (Use your constant sheet to find a and b). Compare this to the answer you would get using the ideal gas law.

$$\left[P + a\left(\frac{n}{V}\right)^2\right](V - nb) = nRT$$

$$P = \frac{nRT}{(V - nb)} - a\left(\frac{n}{V}\right)^2$$

$$P = \frac{(0.500mol)\left(0.08206\frac{Latm}{molK}\right)(298.2)}{(1L - (0.500mol)(0.0391L/mol)} - (1.39\frac{atmL2}{mol2})(\frac{0.500\ mol}{1.0\ L})^2$$

=12.13 atm

V. Gas Stoichiometry

1. Consider the combustion of liquid hexane

$2\ C_6H_{14}\,(l) + 19\ O_2\,(g) \rightarrow 12\ CO_2\,(g) + 14\ H_2O(l)$.

If 1.52-g of hexane is combined with 2.95 L of oxygen at 312K and 890 torr. The carbon dioxide gas is collected at 297 K and 0.930 atm. What volume of carbon dioxide gas will be collected assuming 100% yield?

Need to determine the limiting reagent

$n_{C6H14} = \frac{1.52\text{ g}}{86.07\text{ g/mol}} = 0.0177\text{ mol vs. } n_{O2} = \frac{PV}{RT}\ \frac{(890\text{ torr}/760\text{ torr/atm})(2.95L)}{(0.08206\text{ atmL/molK})(312K)} = 0.135\text{ mol}$

$0.135/19 < 0.0177/2$ so O_2 is the LR $0.135\text{ mol } O_2\,\frac{(12\text{ mol }CO_2)}{(19\text{ mol}O_2)} = 0.0853\text{ mol }CO_2$

$V = \frac{nRT}{P} = \frac{(0.0853\text{ mol})(0.08206\text{ atmL/molK})(297K)}{(0.93atm)} = 2.23\text{ L}$

2. A 3.54-g sample of lead(II) nitrate (molar mass = 331 g/mol) is heated in an evacuated cylinder with a volume of 1.60 L. The salt decomposes when heated, according to the following equation:

   $2\ Pb(NO_3)_2\,(s) \rightarrow 2\ PbO\,(s) + 4\ NO_2\,(g) + O_2\,(g)$

   Assuming complete decomposition, what is the pressure (in atm) in the cylinder after decomposition and cooling to a temperature of 300. K? Assume the $PbO_{(s)}$ takes up negligible volume.

   The reaction produces 2 gases so the pressure in the container is the total pressure $\Rightarrow P_{total} = \frac{n_{total}RT}{V}$

   $3.54\text{ g } Pb(NO_3)_2\frac{(1\text{mol } Pb(NO_3)_2)}{(331\text{ g } Pb(NO_3)_2)} \text{x} \frac{(4\text{ mol } NO_2 + 1\text{mol } O_2)}{2\text{ mol } Pb(NO_3)_2} = 0.0276\text{ mol gas}$

   $P_{total} = \frac{(0.0267\text{ mol})(0.08206\text{atmL/molK})(300K)}{(1.6L)} = 0.41\text{atm}$

3. 2.5 mol of O_2 gas and 3.0 mol of solid carbon, C (s) are put into a 3.50-liter container at 23°C. If the carbon and oxygen react completely to form CO (g), what will be the final pressure (in atm) in the container at 23°C?

$2\ C\,(s) + O_2\,(g) \rightarrow 2\ CO\,(g)$

2 C (s)	*O_2 (g)*	→	*2 CO (g)*
3 mole	*2.5 mole*		*0 mole*
-3	*$-3(\frac{1}{2})$*		*$+3(\frac{2}{2})$*
0	*1 mole*		*3 mole*

Determine limiting reagent

$C \Rightarrow 3\text{ mol C}/2 = 1.5$

$O_2 \Rightarrow 2.5\text{ mol}/1 = 2.5 \Rightarrow$ C is the LR

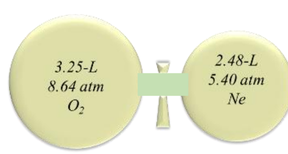
Since C is the LR $\Rightarrow$ in addition to the CO formed there will be excess O_2 in the container so the pressure will be the total pressure

$\Rightarrow P_{total} = n_{total}RT/V$

Since there is 4 mol of gas in the container $P_{total} = \frac{(4\text{ mol})(\frac{0.08206\text{ atmL}}{\text{molK}})(23+273\text{ K})}{3.5\text{ L}}$

$P_{total} = 27.8\text{ atm}$

4. The valve between two tanks is opened. See below. Calculate the total pressure in the container after the valve is opened.



Each gas is affected by the valve opening $\Rightarrow \frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$ where n <u>and</u> T are constant

solving for $P_2 \Rightarrow P_2 = \frac{P_1V_1}{V_2}$

for $O_2 \Rightarrow P_2 = \frac{(8.64\text{ atm})(3.25\text{ L})}{(3.25L+2.48L)}$

$P_2 = 4.9\text{ atm}$

for Ne $\Rightarrow P_2 = \frac{(5.4\text{ atm})(2.48\text{ L})}{(3.25L+2.48L)} = 2.3\text{ atm}$

Total pressure = 4.9 atm + 2.3 atm = 7.2 atm